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Description	Assessment of the observing system fitness for HAB warning bulletin in the Atlantic
Work Package number	WP8
Work Package title	Societal benefits from observing/information systems
Lead beneficiary	MI
Lead authors	Caroline Cusack, Manuel Ruiz-Villarreal, Wenche Eikrem, Trine Dale and Julie Maguire
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Stakeholder engagement relating to this task*

WHO are your most important stakeholders?	☒ Private company – see below under "others" If yes, is it an SME ☒ or a large company ☐? ☒ National governmental body ☐ International organisation ☐ NGO ☒ others Please give the name(s) of the stakeholder(s): Norway: (a) Norwegian Food Safety Authority (b) Miljødirektoratet, Norway (c) Vetrinærinstituttet, Norway (d) Institute of Marine Research, Norway (e) Fish farming industry (f) Shell producing companies Spain: (g) INTECMAR, Xunta de Galicia (h) Consellería do Mar, Xunta de Galicia (i) Aquaculture mussel farmer associations Ireland: (j) Dept. of Agriculture, Food & the Marine (k) Food Safety Authority Ireland (l) other relevant government departments and local authorities (m) Aquaculture industry (Shellfish and Finfish aquaculture industry, Irish Farmers Association - Aquaculture, Irish Shellfish Association, Irish Salmon Growers' Association Ltd.) (n) Molluscan Shellfish Safety Committee
WHERE is/are the company(ies) or organization(s) from?	☒ Your own country ☐ Another country in the EU ☐ Another country outside the EU Please name the country(ies): Norway, Spain & Ireland

Is this deliverable a success story? If yes, why? **If not, why?**	☒ Yes, because the information compiled, from many sources, into the weekly HAB-bulletin is readily accessible and provides information on the current HAB situation with expert advice provided to the public and stakeholders on the HAB outlook for the week ahead. ☒ No, because in some countries, e.g., Norway, financial support is not guaranteed to ensure continued publication and enhancement of the HAB-bulletin.
Will this deliverable be used? **If yes, who will use it?** **If not, why will it not be used?**	☒ Yes, in Spain and Ireland Yes, it is already in use by scientists, regulators and the aquaculture industry. Continued publication of the HAB-bulletin has stakeholder support in Ireland and the INTERREG Atlantic Area project "PRIMROSE" will ensure its continued use and enhancement in Spain and Ireland. The PRIMROSE project will extend HAB bulletin development in other EU countries (e.g., UK, France, Portugal) and will facilitate automation of the production of products in the bulletin. Plans are also in place to enhance the bulletin with the addition of new products and services (e.g., shellfish bacterial contamination to account for microbial risk, e.g., *Escherichia coli*, Norovirus, Vibrio results from microbiological tests related to the winter vomiting bug). ☒No, for Norway Financial support for the continued publication of the bulletin in Norway has yet to be secured.

NOTE: This information is being collected for the following purposes:

1. To make a list of all companies/organizations with which AtlantOS partners have had contact. This is important to demonstrate the extent of industry and public-sector collaboration in the obs community. Please note that we will only publish one aggregated list of companies and not mention specific partnerships.
2. To better report success stories from the AtlantOS community on how observing delivers concrete value to society.

*For ideas about relations with stakeholders you are invited to consult D10.5 Best Practices in Stakeholder Engagement, Data Dissemination and Exploitation.

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Glossary: Definitions, Acronyms and Abbreviations

Name/Acronym	Meaning
Characteristic	Essential / Environmental Ocean Variable of the upstream data used to create the data products A distinguishing feature that refers to either: – a variable (e.g., EOV) derived from the observation, – the measurement or the numerical model output of a phenomenon or of an object property in the environment The geographical representation of an object on a map (i.e. a layer such as a protected area, a coastline or wrecks) by a set of vectors (polygon, curve, point) or a raster (a spatial data model that defines space as an array of equally sized cells such as a grid or an image).
EMODnet	European Marine Observation and Data network (DG Mare) with discipline-based themes, an EU programme to support the further development of an Integrated Maritime Policy (Reg. EU 1255/2011)
EOVs	Essential Ocean Variables (EOVs) are the fundamental physical, biogeochemical, and biological measurements required to understand ocean phenomena well enough to provide applications that support Societal Benefits.
Fitness for Purpose	Rationale for creating a dataset “fitness for purpose” of the datasets used to help create (and validate) the product. “fitness for purpose” is evaluated by the producer according to the specifications of the quality expected for his / her purpose.
Fitness for Use	Rationale for selecting the dataset “fitness for use” (e.g., end-user satisfaction) of the science-based products for the benefit of civil society. “fitness for use” of a dataset is evaluated by the user according to the specifications of the quality expected for his / her use
HABs	Harmful Algal Blooms are biological events caused by a small number of phytoplankton species. There are two main types of HABs • High biomass blooms that produce toxins harmful to marine fauna and farmed fish/shellfish and/or cause anoxic conditions to occur resulting in environmental conditions that are unfavourable to marine life and farmed species. Blooms can occur naturally, although in some parts of the world such as Hong Kong and parts of the USA the proliferation of certain HAB species have been attributed to anthropogenic nutrient enrichment. • Low biomass blooms that produce biotoxins can accumulate in shellfish and throughout marine food-webs. If consumed by humans a variety of illnesses can result, the severity of which depends on the causative organisms and the biotoxins they produce.

Name/Acronym	Meaning
Input datasets	This is the collection of existing data used as the input to produce the end- Use-Case products and services. Data is collected by sensors at a place and time and are typically repeated periodically to monitor change over time. Data can be raw or processed to make it interoperable with other data. A lot of the data collected from the data networks and other sources are assembled and shared thanks to the European Marine Observation and Data Network (Thematic Assembly Groups), the Copernicus programme, the Data Collection Framework for Fisheries. Other datasets are made available via national and international open access databases. Input data or upstream data or monitoring data A collection of relevant data, catalogues of the data sources and the development of specific products from available primary and assembled datasets in view of the specific questions for each challenge, providing confidence limits (service)
NMP	National Monitoring Programme
Product specification	Describes the rationale for creating a dataset
Product/Service	SOLUTION to an end-Users PROBLEM
TRL	Technology Readiness Level
Usability	The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use.
Use-Case	The AtlantOS Task i.e. pilot action / feasibility study
Use-Case / Pilot Action	Synonymous of AtlantOS Task
Use-Case product	Targeted product build from “input data sets” that are related to “characteristics”

Executive summary

The AtlantOS WP8 targeted products address five GEO/GEOSS societal benefit areas related to climate, disasters, ecosystems, health and water. AtlantOS WP8 seeks to demonstrate the value and societal benefit of the existing observing system in the Atlantic through eight pilot actions. This report provides a description of the input data sets used in the Use-Case Pilot Action on “Harmful Algal Blooms”, part of AtlantOS Work Package 8 “Societal Benefits from observing/information systems” of H2020 AtlantOS project. A data adequacy summary, highlighting important gaps in the observing system, based on “expert opinion” is provided for the Harmful Algal Bloom (HAB) bulletin. The report focuses on the ability of the targeted product (i.e. the HAB bulletin) to ‘sufficiently satisfy a requirement or meet a need’ of the end-users. The content of the bulletin is an evolving process centred on user needs. Key to developing a useful HAB bulletin, is first to understand the End-Users problem/need, and then to produce a product that customers value. The “fitness for purpose” assessment of the datasets used to create (and validate) the HAB bulletin was enhanced using information gathered through feed-back on the product from the End-Users; who provided a list of further improvements that can be used to enhance the usability of the current HAB bulletin. The stakeholder engagement process was also examined, and the gaps identified can further guide future efforts to improve the content of the HAB bulletin.

Introduction

The Harmful Algal Bloom (HAB) bulletin provides information on the current and the potential future state of HABs and biotoxins over the next three days. The targeted end product is an online HAB bulletin [pdf format] as described in AtlantOS Deliverable 8.6 (Cusack *et al.* 2018); D8.6 includes information on the identified user requirements, a list of the target users for the Use-Case and their needs, stakeholder engagement results, a description of the methodology used to produce the targeted product components, and a graphical layout of the HAB bulletin in Norway, Ireland and Spain.

The input datasets used to create a bulletin include *In-situ* data from the national/regional HAB and biotoxins monitoring programmes, available ocean observations data from buoys, floats etc., remote sensing data (SST and ocean colour) from satellites and available numerical hydrodynamic modelled data outputs. The data are processed, organised and presented as visual information data products in the bulletin. These components in the bulletin are enhanced with the provision of text by a local expert who evaluate and interpret the results and provide a summary and short-term prediction on the first page of the HAB bulletin.

In this report, we take a closer look at the upstream data used to create a HAB bulletin. The EMODnet Checkpoint product assessment methodology was applied using the “Expert opinion” option to determine, the "Fitness for Use" of the input datasets to create the data products in the bulletin, and with the help of the End-Users the "Fitness for Purpose" of the targeted product, the HAB bulletin (e.g., end-user satisfaction). The assessment investigates if available data are appropriate to provide a useful customer targeted HAB bulletin product (output). This is followed by a discussion on what future improvements could enhance the bulletin. Gaps in the stakeholder engagement process were also examined to help guide future activities co-developing science-based products.

Use-Case Product Technology Readiness Level

The Technology Readiness Level (TRL) of the HAB bulletin was assessed by the scientists in each region (Norway, Ireland and Spain) using the TRL guidelines in Table 1 below. The Norwegian bulletin was given a TRL of 4 - 6, the Irish bulletin, a TRL of 7 – 9 and the Spanish bulletin, a TRL of 6. The TRL ranges assigned for the Norwegian and Irish bulletins relate to the different TRLs of data product components within the bulletin.

Table 1. Technology Readiness Levels (TRL) to define different research and innovation steps going from basic research to the commercialisation of a product.

TRL	Definition
TRL 1	Basic principles observed and reported
TRL 2	Technology concept and/or application formulated
TRL 3	Analytical and experimental critical function and/or characteristic proof-of-concept
TRL 4	Component and/or subsystem validation in laboratory environment
TRL 5	Component/subsystem/system validation in relevant environment
TRL 6	Demonstration in relevant environment
TRL 7	Prototyping demonstration in an operational environment
TRL 8	Actual system completed and qualified through test and demonstration
TRL 9	Actual system proven through successful operations

Use-Case Products description

Information in the HAB bulletin for HABs and biotoxins are derived from single *In-situ* points in the target geographic region (Norway, Ireland and Spain), satellite data (SST, chl) and in the case of Ireland and Spain data outputs from coastal numerical hydrodynamic models (currents). Descriptions and file formats of the individual components of the bulletin are included in the AtlantOS D8.6 report (Cusack *et al.* 2018) and in Leadbetter *et al.* (2018). The summary below lists the types of data product components in a HAB bulletin. Note: the number and type of science-based data products in each regional HAB bulletin varies.

Data product component types delivered to the user in the HAB bulletin

- ***In-situ* HAB & Biotoxin products**

  Subcomponents:
  - HAB & Biotoxin current conditions
  - Biotoxin prediction
  - Biotoxin historic trends
  - HAB & Biotoxin distributions and abundances in recent weeks
  - HAB & Biotoxin weekly trends for the current year
  - Top five most abundant phytoplankton taxa

- **Remote sensing products**

  Subcomponents:
  - Chlorophyll *a* levels and distribution
  - Chlorophyll *a* anomaly levels and distribution
  - Sea Surface Temperature (SST) levels and distributions

- ***In-situ* ocean observing products**

  Subcomponents:
  - *In-situ* Chlorophyll a
  - *In-situ* Sea Surface Temperature
  - *In-situ* Sea Surface Salinity
  - Upwelling index

- **Model simulation products**

  Subcomponents:
  - Simulated surface to bottom water properties (temperature, salinity, density)
  - Simulated volumetric fluxes
  - Simulated Lagrangian particle tracking

Data types and variables used to create the bulletin

- Laboratory analytical results
  - Phytoplankton biomass and diversity
  - Biotoxins / Phycotoxins
  - *In-situ*, delayed mode data (fixed points)
  - Phytoplankton biomass and diversity
- *In-situ* data of Sea Surface Temperature, Salinity, Chlorophyll
- Earth Observation data (Sea Surface Temperature and Chlorophyll)
- Numerical model outputs of Surface currents and Subsurface currents, Salinity, Temperature and Density
- Particle tracking model outputs

Use-Case Product specifications

AtlantOS Deliverable 8.6 (Cusack *et al.* 2018) describes the scope of the use case, the characteristics / Essential Ocean Variables (EOVs) and data sources used in the Products. The Irish "Best" Practice on how to create a weekly bulletin provides further information (Leadbetter *et al.* 2018). Metadata information (Table 2 below) on the data product components in the HAB bulletin for each case study in Norway, Ireland and Spain are stored here. These are the quality elements / data properties used as an input to produce the data products (i.e. upstream data) such as spatial resolution, temporal resolution, temporal coverage, etc. are provided in these metadata tables.

Table 2. Data product component specification used to summarise the datasets.

Product component specification	
Product component name	
Product component description	
Geographic description	*Use name of sea area or conventional name by users*
Horizontal extent	*Give latitude, longitude of sea area bounding box*
Horizontal resolution	*Give lat. long resolution (fraction of lat, long) of products if in a grid, station locations if stations, etc.*
Horizontal accuracy	*Give an estimate of the accuracy in defining the product grid or the station locations or define the closeness of coordinate values to values accepted as or being true, e.g., on the base of instrumentation used*
Vertical extent	*Approximate range of depth where the product is significant (surface if the product is only surface, surface-to-bottom if the product is defined in the whole water column, etc.)*
Vertical resolution	*Give number of depth or layers where the product is defined if possible*
Vertical accuracy	*Give an estimate of the accuracy in defining the product vertical grid (if the product is only surface or one layer please try to define what "surface" means or how the layer was defined)*
Temporal extent	*Give an estimate of the time period where the product is defined to be relevant*
Temporal resolution	*Give the time resolution (hourly, daily, weekly, monthly, annual, etc.) of the product*
Temporal accuracy	*Give an estimate of the errors involved in the definition of the product time resolution*
Spatial representation	*Give a description of the specific graphical representation of the results*

Upstream Data and Targeted Data Products Fitness

Criteria for Expert evaluation of the Targeted Product Quality & Gaps in the Input Datasets

The objective is to provide an expert evaluation of the "fitness for purpose" for each Targeted Product (Pinardi *et al*., 2017).

The methodology helps us to evaluate the quality of the data from current monitoring systems in terms of their accessibility, availability, multiple-use, efficiency, reliability, time consistency, space consistency, as well as the planning of technological advancements, new accessibility, new assembly protocols and observational priorities.

1. Assign an overall product quality score with respect to scope (fitness for purpose) and explain why, according to the scale in Table 3 below.
2. Identify the most important characteristic needed for the Targeted Product quality (if all characteristics are important please say so)
3. Identify the quality element(s) of the most important characteristic(s) that affects the Targeted Product quality.
4. Identify the limitations on the quality of the Targeted product due to the input data set used.
5. Explain which characteristics "fails the most" to meet the scope of the Targeted Product.
6. Provide an expert judgement of the most important gaps in the input data sets for the Targeted Product.

Table 3. Scale used to determine "Fitness for purpose and use" of the Targeted Product (i.e. the HAB bulletin)

Score	Result	"Fitness for purpose and use" of the Targeted Product
1	EXCELLENT	completely meets the scope of the Targeted Product
2	VERY GOOD	meets > 70 % of Targeted Product scope
3	GOOD	meets < 50 % of the Targeted Product scope
4	SUFFICIENT	does not really meet the scope but it is a starting point
5	INADEQUATE	does not really fulfil the scope and is not usable

Overall Product Quality Score

- Requirement of the service (following Maguire, 2011).
- The phytoplankton species / biotoxin present and the severity.
- The risks associated with the phytoplankton species / toxin.
- A prediction of the bloom dynamics over time.
- Hot spot locations of where a bloom is "likely" to occur.
- Highlight when a bloom has occurred in neighbouring regions.
- Notification of a "likely bloom" should be sent by text and a short bulletin should be made available online to download.

Norwegian HAB bulletin: AtlantOS_T8.1_Product_1

[naming convention of AtlantOS products = "ATLANTOS_T#_Product_#"]

1. The overall product quality score of the HAB bulletin with respect to "fitness for purpose" (scope):

   "Sufficient".

   The existing bulletin includes data products that provide a useful overview of the recent severity of HABs and associated biotoxins in Norwegian waters with information from local experts on the current status, associated risk and a prediction for the days ahead. A drawback of the current bulletin, is that it is a static PDF document and that biological and chemical *In-situ* data are currently unavailable to include in the bulletin.

2. Most important characteristics (variables) for the Targeted Product (HAB bulletin) quality:

   For this product the most important characteristics are the *In-situ* HABs and biotoxins concentrations.

3. Quality element of the most important characteristics (variables) that affects the Targeted Product:

   Higher frequency HAB and biotoxin data from inshore and offshore would significantly enhance the HAB bulletin. This it is currently not possible, without further advances of *In-situ* ocean observing technologies that can send biological and chemical data in near real time / at higher frequencies (e.g., daily) from target sites.

Table 4. Fitness of the variable datasets used to create the data products used in the Norwegian bulletin.

Data Product type	**Completeness** *Are the data values missing or unusable?*	**Timeliness** *Is the data available for use in the time frame in which it is expected?*	**Conformity** *Does the data meet expected format?*	**Spatial Coverage** *Is the data available for use in which it is expected in the spatial domain?*	**Accuracy** *Do data accurately represent the real-world as expected?*
In-situ HABs & Biotoxins	No	Yes	Yes*	Yes	Reasonably**
In-situ	No	Yes	Yes	Yes	Yes
Remote sensing products (SST & Chl *a*)	No	No	Yes	Yes	Yes
Model simulation products	Yes***	-	-	-	-

*The sampling frequency of the existing National Monitoring Programme (NMP) conforms to Norwegian legislation.

**Results from the laboratory samples are of high quality with Laboratory methods that are accredited by the Norwegian Authorities. HABs and Biotoxin concentrations in the wild are heterogeneously distributed (e.g., often found in subsurface thin layers) and it is very difficult to get samples that accurately represent an environment constantly in flux. However, the product provides a good idea of the state of play in terms of cell numbers and biotoxin concentrations at the time of sampling.

***Data are missing.

4. Limitations of the quality of the targeted products due to input dataset:

   The National Monitoring Programme (NMP) was the most important database and it was satisfactory to create the science-based data product components in the bulletin. National Monitoring Programme samples are collected only once a week at selected point sites around the coast (and monthly at some sites during low toxicity risk periods) and analysed. This restricts the spatial and temporal resolution of the HAB species and biotoxin data products in the bulletin.

5. Characteristics that fail to meet the scope of the targeted product:

Overall, the data sources used to meet the scope of the HAB bulletin contained the best available options at the time of development.

6. Expert judgement of the most important gaps in the input data sets for the Targeted Product:

   Numerical models have yet to be developed for use in the pilot Norwegian HAB bulletin.

Irish HAB bulletin: AtlantOS_T8.1_Product_2

[naming convention of AtlantOS products = "ATLANTOS_T#_Product_#"]

1. The overall product quality score of the HAB bulletin with respect to "fitness for purpose" (scope):

   "Good" to "Very Good".

   The existing bulletin includes science-based data product components that provide a useful overview of the recent severity of HABs and associated biotoxins in Irish waters with information from local experts on the current status, associated risk and a prediction for the days ahead. A drawback of the current bulletin is that it is only produced weekly as a static PDF document and that offshore biological and chemical *In-situ* data are currently unavailable to include in the bulletin.

2. Most important characteristics (variables) for the Targeted Product (HAB bulletin) quality:

   For this product the most important characteristics are the *In-situ* HABs and biotoxins concentrations.

3. Quality element of the most important characteristics (variables) that affects the Targeted Product:

   Higher frequency HAB and biotoxin data inshore and offshore would significantly enhance the HAB bulletin. This is currently not possible, without further advances of *In-situ* ocean observing technologies that can send biological and chemical data in near real time / at higher frequencies (e.g.,daily) from target sites.

Table 5. Fitness of the variable datasets used to create the data products used in the Irish bulletin.

Data Product type	**Completeness** *Are the data values missing or unusable?*	**Timeliness** *Is the data available for use in the time frame in which it is expected?*	**Conformity** *Does the data meet expected format?*	**Spatial Coverage** *Is the data available for use in which it is expected in the spatial domain?*	**Accuracy** *Do data accurately represent the real-world as expected?*
In-situ HABs & Biotoxins	No	Yes*	Yes	Yes	Reasonably**
In-situ SST	No	Yes	Yes	Yes	Yes
Remote sensing products (SST & Chl *a*)	No	Yes	Yes	Yes	Yes
Model simulation products	No	Yes	Yes	Yes	Reasonably***

*The sampling frequency of the existing NMP conforms to EU legislation.

**Results from the laboratory samples are of high quality with Laboratory methods at the Marine Institute are accredited by the Irish National Accreditation Board (INAB) to ISO/IEC 17025:2005 and The Marine Institute co-ordinates and manages the International Phytoplankton Intercomparison exercises. HABs and Biotoxin concentrations in the wild are heterogeneously distributed (e.g.,often found in subsurface thin layers) and it is very difficult to get samples that accurately represent an environment constantly in flux. However, the product provides a good idea of the state of play in terms of cell numbers and biotoxin concentrations at the time of sampling.

***Whilst Bantry Bay is resolved at adequate resolution by the existing model, in the case of Killary Harbour, only offshore physical simulations of waters outside the fjord are available. A high-resolution model within the fjord would greatly enhance our current understanding of the transport mechanisms into the fjord. See Dabrowski *et al.* (2016) and Cusack *et al.* (2016) for details on numerical model performance.

4. Limitations of the quality of the targeted products due to input dataset:

   The NMP was the most important data base and it was satisfactory to create the science-based data products in the bulletin. However, *In-situ* data for HABs, biotoxins are currently unavailable from offshore shelf waters where HAB populations develop, carried in coastal currents to the mouth of bays where they can be transported inshore into areas where aquaculture activities are carried out. National Monitoring Programme samples are collected only once a week at selected point sites around the coast (and monthly at some sites during low toxicity risk periods) and analysed. This restricts the spatial and temporal resolution of the HAB species and biotoxin mapping data products in the bulletin.

5. Characteristics that fail to meet the scope of the targeted product:

   Overall, the data sources used to meet the scope of the HAB bulletin contained the best available characteristic/variable options at the time of development.

6. Expert judgement of the most important gaps in the input data sets for the Targeted Product:

   The biggest limitation of HAB predications is availability of *In-situ* HABs and biotoxin ocean observing datasets in the shelf seas. Having these types of data available would greatly assist in the development of ecosystem numerical models that can reliably simulate real world HAB events at high temporal and spatial resolution.

Spanish HAB bulletin: AtlantOS_T8.1_Product_3

[naming convention of AtlantOS products = "ATLANTOS_T#_Product_#"]

1. The overall product quality score of the HAB bulletin with respect to "fitness for purpose" (scope):

   Good. The bulletin is very useful as it allows farmers to modify their production schedules according to the forecast. This is of huge benefit as it takes a lot of the guesswork out of harvesting. There was a positive response on the content of the current bulletin when compared to not having it at all.

2. Most important characteristics (variables) for the Targeted Product (HAB bulletin) quality:

   In-situ HAB phytoplankton concentration and Lagrangian particle transport visualization for assessing along-shore transport and retention and transport between rías.

3. Quality element that affects the Targeted Product:

   Higher frequency HAB data in monitoring stations and on the shelf would significantly enhance the HAB bulletin. Information on biotoxins is missing. If bulletins are issued in a period when many polygons are closed, the information that can be obtained from the bulletin and the modelling tools in use is limited since no biotoxin data or models for detoxification are available. However, in situations when harvesting areas are open, the bulletins are more useful because they can forecast the risk of transport of HAB species driven by along-shore and across-shore currents.

Table 4. Fitness of the variable datasets used to create the data products used in the Spanish bulletin.

Data Product type	**Completeness** *Are the data values missing or unusable?*	**Timeliness** *Is the data available for use in the time frame in which it is expected?*	**Conformity** *Does the data meet expected format?*	**Spatial Coverage** *Is the data available for use in which it is expected in the spatial domain?*	**Accuracy** *Do data accurately represent the real-world as expected?*
In-situ HABs & Biotoxins	Yes*	Yes	Yes**	Yes	Reasonably***
In-situ	No	Yes	Yes	Yes	Yes
Remote sensing products (SST & Chl *a*)	No	Yes	Yes	Yes	Yes
Model simulation products	No	Yes	Yes	Yes	Reasonably****

*No biotoxin data shown in bulletins

**The sampling frequency of the existing NMP conforms to EU legislation.

***Results from the laboratory samples are of high quality with Laboratory methods at the Galician HAB monitoring agency INTECMAR are accredited by the Spanish Accreditation Board (ENAC) to ISO/IEC 17025:2005. IEO and INTECMAR participate in international groups and intercomparisons that ensure the quality of HAB phytoplankton determinations HABs concentrations in the wild are heterogeneously distributed (e.g., often found in subsurface thin layers) and it is very difficult to get samples that accurately represent an environment constantly in flux. However, the product provides a good idea of the state of play in terms of cell numbers at the time of sampling.

****See Ruiz-Villarreal *et al.* (2016) for details on model performance.

4. <u>Limitations of the quality of the targeted products due to input dataset:</u>

   In late summer and autumn, Lagrangian particle tracking simulations are run routinely for estimating along-shore transport from the northern Portuguese shelf to Galician harvesting areas. However, these simulations should be complemented with information on the presence or absence of HAB species obtained by Portuguese HAB monitoring, i.e., Portuguese monitoring data should be incorporated to the input dataset to know whether biotoxin producing species have been detected previously in Portuguese areas. Information of HAB species presence in shelf areas is a gap.

5. <u>Characteristics that fail to meet the scope of the targeted product:</u>

   No biotoxin data is incorporated to the bulletin so far.

6. <u>Expert judgement of the most important gaps in the input data sets for the Targeted Product:</u>

   The bulletin is a static document, so is very useful when it is issued and less so as times goes by. The current bulletin needs to become more automated, so maps and graphs are updated as soon as new data is generated. Toxin data should be incorporated into the bulletins to provide additional information to status reports on the openings/closures of harvesting areas.

Summary

The AtlantOS task 8.1 on HABs shows that integrating information from HAB monitoring programs, *In-situ* networks (physical and limited biochemical data), satellite imagery and hydrodynamical numerical models, as blended products in a HAB bulletin, is very useful to the stakeholders. The physical numerical model outputs help with predictions of the likely HAB transport, however, information on HAB and biotoxin concentrations in offshore waters is currently unavailable and scientific information on HAB initiation in shelf waters remains elusive. This highlights a need to advance the integration of physical and biological numerical models with the development of more integrated ecosystem models. In order to create useful simulations, *In-situ* ocean observing gaps must be filled to help validate and constrain the models that are used to build downstream products. A good example to demonstrate how ocean observing greatly helps to correct numerical model inadequacies is the use of physical data from the Argo network.

Recommendations for system improvements

Since a product's value is solely in its ability to solve a customer's problem, stakeholder engagement is essential to achieve a successful outcome. Cusack *et al.* (2018; D8.6) lists the gaps identified by the End-Users in the current HAB Bulletin. To summarise, End-Users find the HAB bulletin useful in terms of getting information about the current state of phytoplankton species and associated biotoxins at aquaculture sites, and the bulletin provides a picture of the severity and outlook each week, regionally. The current HAB bulletin (Targeted Product) is produced as a PDF and, since it is static, it is not as user-friendly as using an interactive web interface that could update maps as data becomes available. While the HAB bulletin is useful at the start of the week it becomes less so as the week progresses. The stakeholders still find the bulletin a helpful decision support tool since it allows farmers to modify their production schedules according to the HAB forecast.

The stakeholders identified several gaps and priorities with the main ones discussed below.

1. Future developments should include *In-situ* biological and chemical observing technologies that help detect phytoplankton, HABs and biotoxins in near real-time with data products updated frequently online. It is evident that there is a need for continuous offshore shelf sea monitoring to detect and track phenomena such as Harmful Algal Blooms. Occurrence and advection of some HAB events are related with the shelf circulation. The lack of HAB observation in shelf waters is strongly linked to a lack of biogeochemical or biological observational data. Biogeochemical EOVs are underrepresented in the HABs Use-Case. The main reason for this, is that BGC *In-situ* data collection coverage in target Use-Case regions are lacking or absent to facilitate useful data product development (see AtlantOS Deliverable 4.5; Akpına *et al.* 2018). For example, maps of dissolved oxygen (DO) levels, in near real-time, would provide useful information in the event of a high biomass HAB since one of the resulting symptoms of environmental water quality deterioration when a bloom subsides is a drop in DO levels. As conditions worsen, hypoxia can lead to massive kills of farmed and wild fish, shellfish and the fauna of natural benthic communities. As for the open ocean, biogeochemical or biological monitoring information are not

available in coastal regions except the near coast where regular sampling is performed (AtlantOS D1.3 Buch *et al.* 2017; AtlantOS D4.5; Akpinar and Charria 2018). Mature ocean observing technologies to monitor oxygen, nutrients, Chlorophyll-*a*, carbon and pH exist, but, they have yet to be extensively deployed. While some progress has been made in recent years, there is still a need for technological advancements to produce robust, low power consumption, low maintenance, reliable, interoperable, low cost sensors that can remain in the field. Glider activity accompanied with novel sensor capabilities (e.g.,chlorophyll, oxygen, pH, multispectral meters, HABs) could greatly assist with the detection of subsurface high biomass HAB layers in shelf waters. The availability of free and open glider data through facilities such as CMEMS in the coming years as the glider network matures would greatly assist the improvement of the HAB bulletin data products. Another area where improvements could be made in the HAB bulletin is the development/use of satellite data products that can identify phytoplankton functional type and HAB specific groups. It is important to note support and funding at national level is a prerequisite to maintaining and operating the ocean observing system as it advances.

2. The current bulletin needs to become more automated, so maps and graphs are updated as soon as new data is generated. The display / dashboard should be interactive, and the user should be able to zoom into a region of interest to find out the latest news on biotoxins and HABs. The INTERREG project, PRIMROSE is currently developing a more interactive and automated targeted product to advance the development of next generation versions of the bulletin.
3. Exchange of data among different national monitoring programs is required for an accurate HAB forecast in situations where along-shore transport from areas in other country play a role (Maguire *et al.* 2016). For example, early risk warnings of autumn potentially toxic dinoflagellate blooms in the Galician Rías is feasible combining Lagrangian particle tracking simulations with data on HAB occurrence from Portuguese monitoring (Ruiz Villarreal *et al.* 2016). Protocols for effective transnational exchange of data among different national monitoring programs are under development in regional cooperation projects like the Atlantic Area PRIMROSE (Predicting Risk and Impact of Harmful Events on the Aquaculture Sector Interreg Atlantic Area EAPA_182/2016) or Galicia-Northern Portugal MarRisk (Interreg POCTEP Spain Portugal, 0262_MARRISK_1_E).
4. Integrating HAB information from monitoring programs and making use of hydrodynamical numerical models complemented with physical and biogeochemical data from *In-situ* networks, and satellite imagery have proven very useful to stakeholders. In fact, we can give predictions of HAB transport, however, we are unable to simulate HAB initiation; this is especially true for low biomass HAB species. There is a high priority need to further advance the integration of physical and biological numerical models with the development of more integrated ecosystem models and to advance the integration of different *In-situ* ocean observing datasets with modelling to finally reach a level where we can predict the initiation of blooms.

Gaps identified in the stakeholder process

While the stakeholder engagement assessment carried out by WP10 partners indicates that stakeholder engagement activities in this task are at quite an advanced stage (Users identified, prioritised and consulted; products identified by Users, User Requirements defined, products solutions developed, outreach conducted, products assessed and

maintained – see AtlantOS Deliverable 8.6 for details), challenges remain. Below is a list of the challenges encountered during stakeholder engagement activities and some suggestions on how these challenges can be overcome.

The main challenges in the stakeholder process are:

1. A **lack of time to engage**.
2. **Stakeholder fatigue**, in other words they are overloaded with engagement activities for different, but, similar projects, lessening their willingness to participate.
3. **Unbalanced engagement**, whereby the dominant sector's opinion is reinforced.
4. **Short term engagement**, stakeholder engagement often only lasts for the duration of the project, making it difficult to deliver the benefits expected by the stakeholders in the time allowed.
5. Engagement can sometimes create **unrealistically high expectations** among stakeholders (e.g.,an annual HAB forecast). Particularly from those who engage early in the research process and subsequently discover their suggestions are unachievable.

To overcome these challenges, suggestions include:

1. **Lack of time** - Try to engage with stakeholders at networking events such as conferences or industry meetings. Conduct semi-structured interviews during breaks and allow the respondent to talk freely. Where possible try to organise a group meeting as part of the event. Training in facilitation and interview techniques is also very useful.
2. **Stakeholder fatigue** - Explain the tangible benefits to stakeholders from engaging with you. Work with "opinion" leaders to persuade others why it is important to take part in the process.
3. **Unbalanced engagement** – Conduct a stakeholder cross-sectoral and multi-disciplinary analysis and prioritise those who should be contacted. Consider who benefits most from the results and who might have the most influence. However, do not neglect stakeholders who are still indirectly interested in the research and may have a minority view.
4. **Short term engagement** – Identify organisations (e.g.,industry associations) that have a long-term presence in the sector. Involve them in the legacy of the outputs, giving them sufficient ownership of the results. Maintain relationships with key stakeholders after the project is ended and lay foundations for future collaborations.
5. **Unrealistic high expectations** – Manage expectations as best you can. Identify new ideas to improve the product that the project team can implement immediately. Update stakeholders regularly and explain what ideas they communicated were adopted and implemented to improve the product, and why some of their recommended changes were not successful or feasible. The project team should always be open to all ideas and embrace the challenge.

Continuation of Service

Support at national level is essential for continuation of this type of service. Sustainability is an issue for some regions/countries to continue publishing a weekly HAB bulletin into the medium and long term with Ireland, one of the few countries in Europe to overcome this issue due to the support from industry, regulators and government.

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